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Effect of Fiber Loading on Mechanical and Physical Properties of Uniaxial Long Kenaf Bast Fiber Reinforced Epoxy Composites

T Venkategowda, Manjunatha L H

Abstract*: In the recent years, due to environmental awareness of general public, researchers and scientists directed towards the use of natural fibers reinforced composites as environmentally friendly. Now a days, many scientists, researchers and engineers have explored the extraction, properties and utilization of natural fibers as economically and effectively as possible to produce good quality natural fiber reinforced polymer matrix composites. Many scientists and researchers proved that increase in fiber loading resulted in increased mechanical properties of the composite material. This will be the basis to develop and to evaluate properties of natural fiber reinforced polymer matrix composites. In this research, Kenaf long fiber reinforced epoxy matrix composites were successfully fabricated by simple and cost effective hand layup technique and their mechanical properties such as tensile strength, bending strength, impact strength, hardness with different fiber loading were successfully investigated. Water absorption capacity was also reported. The fibers are treated with NaoH solution for surface modification and to improve mechanical properties. The specimens are prepared according to ASTM standard and experiments were carried out.

Keywords: Kenaf, Epoxy, Alakli treatment, Sodium hydroxide, Mechanical tests, Moisture absorption.

I. INTRODUCTION

Judicious combination of two or more materials is called Composite material in which one of the materials called reinforcement is imbedded in other material called matrix material. The reinforcement is generally in the form of fibers, mats and particles. The matrix which is more ductile and less hard holds the reinforcement and acts as strong load carrying medium protecting the fibers from chemical and environmental attack. The matrix is usually continuous phase and reinforcement is discontinuous phase. The discontinuous phase is harder and stronger than the continuous phase. Use of composite material is possible to reduce vehicle weight and fuel efficiency reducing CO_2 emission.

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Correspondence Author
T Venkategowda*, Department of Mechanical Engineering, Maharaja Institute of Technology, Thandavapura, Mysuru, Karnataka, India.
Dr. Manjunatha L H, Department of Mechanical Engineering, REVA University, Bangalore, Karnataka, India.

Now a days, the use of natural fibers as reinforcement in polymers has received a great deal of attention from researchers due to their light weight, low cost, high specific modulus, renewability, easy availability, biodegradability and environment friendliness. The natural fibers include banana, coir, kenaf, jute, flax and many others. Recently, natural fiber reinforced polymer composites have been extended advanced applications such as automotive, aircraft, medical, sports, food and packaging industries. The main drawback of plant fibers is hydrophilic nature which leads to high moisture absorption, insufficient adhesion between untreated fiber and polymer matrix, poor wettability, poor dimensional stability and restricted processing temperature.

II. MATERIALS, EQUIPMENT'S AND METHODS

A. Kenaf Fiber

In this work, long Kanaf fiber (Cannabinus –hibiscus) procured from Guntur, Andhra Pradesh, was used as reinforcement due to its high toughness and high aspect ratio. Kenaf or Hibiscus Cannabinus fiber having good mechanical and physical properties is available in some places. Southern Asia is probably the native of Hibiscus Cannabinus but its exact natural origin is unknown till today. The fiber forms are the long bast fibers. The Kenaf fiber has a density of 1.2-1.4 gm/cm^3, tensile strength of 240-930 MPa and elastic modulus of 14-53 GPa.

Fig. 1.Kenaf bast fiber

Fig. 2. Kenaf stem

Fig. 3.Kenaf plant

B. Epoxy and Hardener

Epoxy is a thermosetting polymer which is mixed with hardener. Epoxy resin LY-556 was used as Matrix because of its strong adhesive property and hardener HY-951 for room temperature curing. The properties of epoxy LY-556 are: density 1-1.4 gm/cm^3, elastic modulus 3-6 GPa, tensile strength 35-100 Mpa, extension at break 1-6%, water absorption 0.1-0.4%, impact strength of 0.3 J/cm and compressive strength of 100-200 Mpa. The epoxy resin and hardener were procured from zenith industrial suppliers, Bangalore.

Fig. 4.Epoxy and hardener

C. Sodium Hydroxide

NaOH was used for chemical treatment of fiber and procured from zenith industrial suppliers, Bangalore.

D. Equipment's

1. Mold box
2. Mold releasing agent (Wax)
3. Mixing bowl and spoon or stick
4. Steel Roller with handle
5. Scissors
6. Hand gloves
7. Digital weighing machine of least count 0.001 gm.

E. Preparation of Mold

Fig. 5.Mold box plates

A mold box having dimension 180 mm X 90 mm X 6 mm with a mold cavity 180 mm X 90 mm X 3 mm was prepared using mild steel plates for making the composite plates. The inner surfaces of the mold plates were chrome plated and finely polished.

F. Chemical Treatment of Fibers

The alkali treatment was used as chemical treatment. The purpose of chemical treatment is to improve mechanical properties of composite. The chemical treatment involves soaking of fibers with alkali solution (NaOH + Distilled water), washing with water and drying in air at room temperature. Alkali treatment removes certain amount of dust particles, wax, lignin, and oil contents without affecting fiber cell wall and depolymerizes cellulose. The chemical treatment results in increase in surface roughness and better mechanical interlocking. It also, increases the number of possible reaction sites which results due to increase in amount of cellulose exposed on the fiber surface. Chemical treatment will also significantly improve the mechanical and dynamic characteristics of fiber-reinforced polymer composites. In this work the Kenaf long bast fibers were soaked in alkali solution (6% NaOH + distilled water) for half day (12 hours) at room temperature. The soaked fibers were taken out and washed and rinsed many times with running tap water. After washing, fibers were dried at room temperature for two days (48 hours) and at hot sun for half an hour to get chemically treated fibers.

Fig. 6.Kenaf fiber soaked in alkali solution

Fig. 7.Treated Kenaf fiber

G. Preparation of Composite Plates

Composite plates were prepared in the form of rectangular plates by hand layup method. Hand layup is one of the oldest and simplest method for composite preparation. The fiber weight fraction varies from 10% to 40%. The process includes placing layers of fibers and mixture of resin and hardener in a sequenced layup.

- Apply the mold releasing agent (spray or wax) on the surface of the mold and leave it for 10 minutes to dry. The purpose of mold releasing agent (wax) is to make easy removal of composite plate and to prevent it from sticking into the mold.
- The epoxy and hardener is mixed in the ratio of 10:1 by weight. The mixing is carried out in the plastic container using spoon slowly in order to avoid air bubbles in the mixture.
- The required amount of mixture of resin and hardener is poured and spared it over the entire bottom surface of mold cavity using a brush or roller. It is important to note that do not pour more mixture, which will produce a thick layer, nor pour mixture less than the required amount, which will produce voids in the plate surface after it is cured.
- Then first layer of fiber is then placed manually. This first layer of fiber should be completely wetted with the previously added mixture of resin and hardener by pressing the fiber gently using a roller. If the placed fiber is not completely wetted, then pour more resin over the top surface of the fiber and spread it again using a roller.
- Next, second layer of fiber is then placed manually and rolling is performed on fiber surface. More care need to be taken during rolling in order to avoid air bubbles.
- Repeat steps until the required thickness is achieved and weight percentage of fiber was obtained. For each time, a roller was used to roll over the fiber surface to remove any air bubbles from it.
- After layup is finished for required thickness, close the mold tightly using screws and allow it for curing for one day at room temperature.
- After allowing for one day curing, composite plate is removed from the mold cavity.
- After the composite plate is post cured at atmosphere for 24 hours of time as per manufacturer's guidance, it is sized into number of specimens as per ASTM standards of different tests.

Table- I: Compositions of prepared composite plate

Plate Nomenclature	Kenaf Fiber (%)	Eopxy (%)
B	90	10
D	80	20
F	70	30
H	60	40

III. MECHANICAL TESTS

After fabrication of the composite plates, the specimens were sized with the help of zig saw and subjected to various mechanical tests according to ASTM standards to determine properties such as tensile strength, impact strength, bending (flexural) strength and hardness. All the mechanical tests were carried out at ambient temperature of 28°±2°C.The mechanical properties of a composite depends upon the number of factors namely: material, fabrication of the specimen, temperature of the testing environment and appearance of surface defects such as voids. It is important to note that mechanical property of a material does not depend on its size of the specimen.

A. Tensile Test

In general, tensile test is a measurement force necessary to break a specimen and to what level the specimen elongates or stretches before failure. Tensile strength is the maximum tensile stress that a specimen can take on the application of tensile loading before failure. The tensile testing has been done as per ASTM D638 on a computerized UTM. Dog – bone (Dumbbell) shaped specimen was used for this test with dimensions of 165 mm x 20 mm x 3 mm on a gauge length of 50 mm. This test involves placing the specimen in a machine and a tensile load is applied at the ends of the specimen until failure occurs.

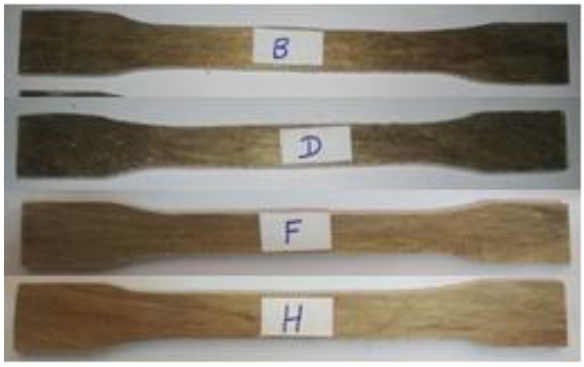

Fig. 8.Prepared tensile test specimens

Table- II: Tensile strength and tensile modulus with different fiber loading

Specimen	Ultimate Tensile Strength (MPa)	Tensile Modulus (MPa)	% Elongation
B	72.773	542.47	13.425
D	96.87	653.84	14.732
F	129.029	798.26	16.072
H	154.249	859.53	17.855

B. Flexural Test (Bending Test)

Bending or flexural strength is the property of a material to resist transverse loads. Bending test is carried out to find extent bending before failure under the action of transverse loads. There are two types of flexural tests to find flexural strength of a material: three-point bending test and four point bending test. In this work flexural strength of the specimen was found using three-point simply supported bending equipment according to ASTM-D790 using rectangular cross section specimen of dimensions 130 mm x 13 mm x 3 mm. This test involves applying a point load at the center of the specimen between two simple supports till it fractures. The distance between the two supports was maintained according to the standard. The specimens were tested on computerized UTM.

Fig. 9. Prepared flexural test specimens

Table- III: Flexural strength and peak displacement with different fiber loading

Specimen	Flexural strength (MPa)	Peak displacement (mm)
B	3.134	2.614
D	6.075	4.031
F	7.65	4.896
H	8.852	6.042

C. Impact Test

In Impact test, load is applied with some initial velocity at a single point of the specimen. Impact test is carried out to measure the resistance of a material to impact load. Impact strength is determined by measuring the amount of energy absorbed by a specimen before failure. Pendulum type impact testing machine was used to perform impact test as per ASTM D256. Single 'V' notch of depth 2.54 mm and angle 45° was created at the center of the test specimen. The specimen is clamped in the vice in the form of vertical cantilever with a V -notch facing the striking hammer. During testing, striker fixed on a pendulum is allowed to fall through a fixed angle to hit free length of the specimen and the corresponding value of energy absorbed by the specimen is noted directly from the digital energy indicator.

Fig. 10. Prepared impact test specimens

Specimen	Energy absorbed (J)	Impact strength (J/m)	Impact strength (J/mm^2)
B	0.1	33.3	0.002
D	0.45	149.9	0.012
F	0.5	166.6	0.013
H	0.9	299.9	0.024

Table- IV: Impact strength with different fiber loading

D. Shore Hardness Test

Hardness is a mechanical property of a material to resist indentation or penetration or scratchiness when it is subjected to compressive loads. Hardness number is measured by different scales depending upon type of the material used. Hardness of polymers and their composites is generally measured by shore scales using durometer. For measuring hardness of soft elastomers, shore A scale will be used and for other polymer materials such as thermoplastics or thermosets shore D scale will be used. In durometer, spring loaded needle-like indenter will be used and the hardness is measured by depth of penetration under the action of load. This test is also known as durometer hardness.

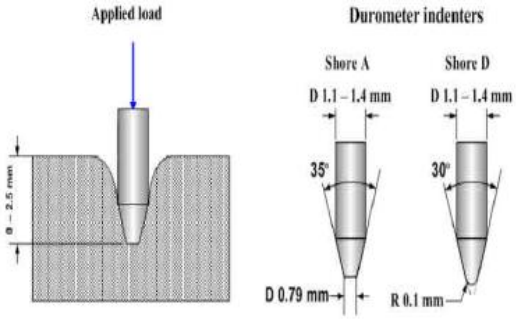

Fig. 11. Shore hardness test principle

Fig. 12. Prepared hardness test specimens

Table- V: Hardness with different fiber loading

Specimen	Hardness(shore-D)
B	65
D	63
F	59
H	53

IV. PHYSICAL TESTS

A. Moisture Absorption Test

Moisture absorption test is used to determine the quantity of water absorbed under specified condition.

The test specimens were manufactured as per ASTM D570. For this test, specimens are dried in an oven for a specified temperature and time and then placed in desiccators for cooling. The specimens are then weighed in an electronic balance of least count 0.001 gm and soaked in water for 24 hrs. The final weight is measured and the difference between the initial weight and final weight is the water absorption capacity of the material. The water absorption is usually expressed as percentage. The following equation is used to establish the percentage of water absorption.

$(W_F - W_I/W_I) \times 100$ (1)

Where W_I = original weight of dry sample and W_F = final weight of wet sample.

Fig. 13. Prepared water absorption test specimens

Table- VI: Water absorption with different fiber loading

Specimen	Water absorption (%)
B	0.99
D	1.72
F	4.82
H	6.21

V. RESULTS AND DISCUSSIONS

It is cleared from the results that mechanical properties are increasing with the increase in fiber loading up to 40%. In the composites beyond 40% of fiber, it is difficult to fabricate the composite due to insufficient quantity of matrix material which leads to more voids formation and decrease in strengths.

VI. CONCLUSION

This research work shows the way of high strength and light weight needed for automobile body components. Utilization of natural fiber composites will give extreme output in the view of fuel economy and leads to the economic upliftment.

1. Tensile strength, bending strength and impact strength of prepared composite are increasing with increase in fiber loading and it is attained maximum at 40% wt. due to the powerful adhesion between the matrix and fiber. Of course with less fiber loading (10%), there is slight decrease in strength which might have occurred due to higher amount of matrix material. Further, it is observed that at around 40% of fiber content, highest strength and modulus have been achieved.
2. The effect of chemical treatment favours the mechanical properties composite. Chemical treatment of fiber causes good bonding with the matrix and increases load carrying capacity of the composite.
3. Hardness is decreasing gradually with increase in fiber loading because as the fiber loading increases, the ductility also increases with decrease in resistance to indentation.
4. The result of effect of fiber loading on the moisture absorption behavior of the composite shows an increasing trend from 10% to 40 % weight fraction. The 40% fiber loading has the highest percentage of moisture uptake. The increasing moisture absorption may attribute to the inability of the matrix material to completely saturate the fiber at higher fiber content. The low moisture uptake of the composite may attributed to the ability of matrix material to prevent water entering the composite at higher matrix content

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AUTHORS PROFILE

T Venkategowda, Associate Professor, Department of Mechanical Engineering, Maharaja Institute of Technology, Thandavapura, Mysuru, Karnataka, India. Prof. T Venkategowda has brilliant experience more than a decade in teaching and research and he is very popular amongst the student fraternity for his outstanding presentation skills. He is currently pursuing Ph.D from Visvesvaraya Technological University, Belagavi, Karnataka, India. He obtained his B.E degree in Mechanical Engineering from Vidya Vikas Institute of Engineering and Technology, Mysuru, Karnataka, India and M.Tech from University B.D.T College of Engineering, Davanagere, Karnataka, India. He has put his experience and knowledge in the form of writing text books; to his credit he authored books on Mechanical Vibrations, Mechanics of Materials and Dynamics of Machinery. Also, he has published many research papers in International Journals.

Dr. Manjunatha L H, Professor at the School of Mechanical Engineering, REVA University, Bangalore, Karnataka, India. Dr. Manjunatha L H has more than two decades of experience in teaching, research and industrial consultancy. He obtained his Master degree in Machine Design and Ph.D from Visvesvaraya Technological University, Belagavi, Karnataka, India. He has published 50 Journal papers and presented technical papers in 28 conferences. He is a Life Member of professional bodies like Indian Society for Technical Education, IAENG, and Member of Association for Machines and Mechanisms. He received Excellent Professional Achievement Award (class 1) from SPE India in Coimbatore, Tamil Nadu and Distinguished Faculty Award VIFA-2018 from Venus International foundation, Chennai.